Operational vulnerability of the high speed rail infrastructure in Malaysia from climate change risks

Kaewunruen, Sakdirat

Operational Vulnerability of the High Speed Rail Infrastructure in Malaysia from Climate Change Risks

Sazrul Leena Binti Sa'adin[1], Dr Sakdirat Kaewunruen[2,*], and Dr David Jaroszweski[3]

[1] *Department of Public Works, Ministry of Interior, Kuala Lumpur, Malaysia*

[2,3] *Birmingham Centre for Railway Research and Education, School of Engineering, The University of Birmingham, Birmingham, B15 2TT UK*

Abstract

Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. Globally the atmosphere and ocean has increasingly getting warmer, the amount of ice on the earth is decreasing, and sea level has risen. The current railway network in Malaysia, over the last decade, has been significantly affected by severe weather conditions such as rainfall, lightning, wind and very high temperatures. These extremes can lead to asset system failure, degraded operation and ultimately, delays to train services. Thus to avoid those disaster happen, such resilience infrastructure is a vital for the new proposed High Speed Railway from Kuala Lumpur, Malaysia to Singapore. Identifying new and innovative way of improving infrastructure, which is resilience during periods of severe weather conditions and as well will secure the operation of HSR once it is open. This study will be focus on the effect of climate change on HSR alignment design in Malaysia, including their operational requirements, local conditions including topographical and geological aspects, together with the operational requirements and local conditions to the design of infrastructure.

Keywords: Operation, Vulnerability, High speed rail system, Climate Change, Risks

1. Introduction

In recent years, there has been increasing interest amongst policy makers across the globe forin building High Speed Rail (HSR), including in Malaysia. In the creation of this new form of transportation, Malaysia needs to ensure that the new HSR will cope and adapt to climate change. In addition, the complexities of climate change and predictions of climate model outputs have introduced an additional measure of uncertainty for railroad operators [1, 2]. Extreme weather has affected railway operations and safety, including fatalities, injuries and property damage. Despite climate change posing serious challenges to infrastructure projects, little research has been conducted in Malaysia into how vulnerable it will be especially in respect to transport infrastructure. It has been widely recognized that there is a need to integrate consideration of climate change and its impacts in development policies and projects [3]. 'Decisions made today – for example, in the creation of new infrastructure or other assets-need to occur in a way which ensures that the outcomes of those decisions are robust enough to cope with, or adapt to, changing climatic conditions in the future' [4].

High Speed Rail from Kuala Lumpur, Malaysia to Singapore (HSR) which is still in its planning stage (at the time of writing), would be the first of its kind in Malaysia. Prime Ministers of Malaysia and Singapore jointly announced the project of HSR on the 19th February 2013 and describe HSR as a 'Game Changer'. The project's target is to be fully operational by 2020. The plan of the HSR network, devised by Malaysia Land Public Transport Commission (SPAD), is to have have 7 stations, 2 Terminus stations, which are in Kuala Lumpur and Singapore. There will be 5 transit stations, 1 each in Negeri Sembilan, Malacca and 3 in Johor. The HSR will have 2 operation systems, which are express, non-stop journey from Kuala Lumpur to Singapore. The estimated journey time is 90 minutes, while HSR Malaysia transit operation will have 7 stops including at terminus station with a 120 minutes journey time. This journey time does not include the waiting time and immigration processing. The trains are expected to run at 300km/hour or faster. However, average speeds will be lower due to the slower speed when approaching stations. Baseline alignment has been developed by SPAD as shown in Figure 1 below, but the detailed

* Corresponding author

E-mail address: s.kaewunruen@bham.ac.uk

alignments remain confidential at this stage. The HSR will have a dedicated line, which is proposed to be a double track on a standard gauge. The HSR project is believed to impact the way of life for Malaysians and Singaporeans in terms on social, politics and economics.

According to SPAD, "the main objective of HSR is to reduce travel time between Kuala Lumpur and Singapore to 90 minutes by strengthening the link between two of Southeast Asia's most vibrant and fast-growing economic engines compared to the 5 to 6 hours journey time by road or 8 hours by conventional train". Although plane travel time is 90 minutes similar to the propose HSR but the hassle of long hours waiting before and after departures will actually give total journey time of 2.5 hours by plane. Contrary to the HSR, passenger still can board the HSR even arrive at the railway station 15 minutes before departure. CBD shown in Figure 2 is Central Business District. The introduction of HSR will increase the daily journey from KL to Singapore and vice versa and at the same time, life quality for both countries people will be improved. The economies of both countries are also intended to benefit.

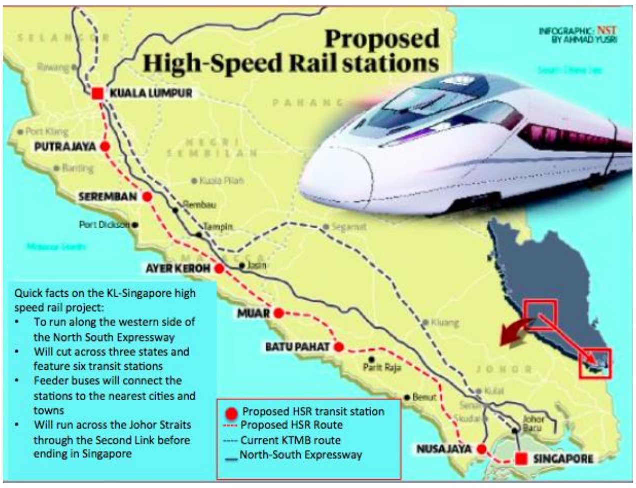


Figure 1: Proposed High Speed Rail Malaysia to Singapore [5]

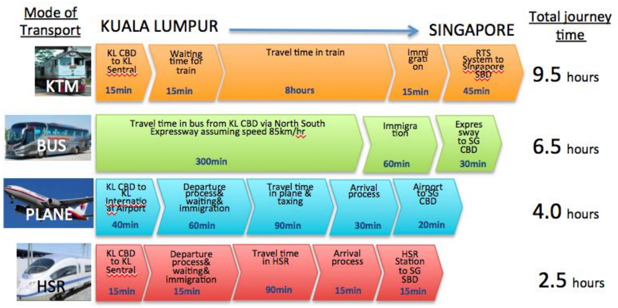


Figure 2: Travelling time from KL to Singapore comparison between KTM, Bus, Plane and HSR [6]

The main objective of this study is to identify the risks and vulnerabilities imposed on the high speed rail system caused by local conditions including topographical, geological and climate change of the proposed HSR route in Malaysia. The study also aims to evaluate how the infrastructure design can satisfy all the operational requirements given the climate impact issues. In carrying out this study, critical literature reviews were carried out. The data of Malaysia HSR are derived from SPAD, and the data of weather are supplied by Malaysian Meteorological Department in order to study the impact of climate change and operational requirement to the design of the infrastructure. The risks due to climate change have then been analysed for potential actions proposed to mitigate the impact.

2. Climate, Geography and Lessons Learnt

Malaysia is divided into 2 parts, Peninsular Malaysia and East Malaysia (refer to Figure 3, which are separated by the South China Sea). Peninsular Malaysia however is further split into 2 parts, the west and east coasts, by the Titiwangsa Mountains. The climate in Malaysia is dominated by 2 monsoon regimes namely the northeast monsoon and southwest monsoon. The northeast monsoon circulates during the months of December, January and February, which is Malaysia's wettest season and the period where the most flooding occurs. Meanwhile the southwest monsoon occurs between the months of May and September, the drier period for the whole country leading to droughts at this period. Being in the equatorial zone and tropical country, the average temperature throughout the year is constantly high (26°C) and has a very high humidity due to the high temperature. Malaysia also has very heavy rainfall which is more than 2500mm per year.

Figure 3: Malaysia Map [8]

"Warming of the climate system is unequivocal and since the 1950s, many of the observed changes are unprecedented over decades to millennia" [6]. According to Malaysia Meteorological Department7, earth surface temperature records have clearly indicated that the climate of the earth is warming, with the rise being due to the increasing concentration of greenhouse gases (GHG) in the atmosphere. Thus in the next 50 year, Malaysia will experience higher temperatures, changing rainfall patterns, rising sea levels and more frequent extreme weather events ranging from drought to floods. The famous Malaysian rail jungle (east coast line) (refer to Figure 4), which is operated by National Malaysia Railway (KTM) was disrupted for almost 6 months due to the massive flood in December 2014. The damage included the railway quarters, signalling, tracks, locomotives, machinery and rolling stock. The disruption affected thousands of workers, traders and children going to school. There is still one stretch of line still not back in operation due to the railway bridge in Kemubu, Kelantan had completely collapsed as evidenced in Figure 5. Operation of the train service in the east coast is expected to be fully operational by February 2016 with the completion of the railway bridge in Kemubu. Construction of the new 250m long bridge across the Nenggiri River is expected to cost RM30 million (GBP4 million)8. This incident should give a lesson to the railway industry and policy makers that extreme weather can have a severe impact to the transportation operations as well as to their infrastructure. Rebuilding railway infrastructure is not easy and is very costly, thus to provide a reliable railway system into the future, studies of the impact of climate change is needed. From these studies, the adaptation of railway infrastructures and rolling stock to the climate change could be established.

Figure 4: Malaysia Rail Map [11]

3. Vulnerability of High Speed Rail Infrastructure in Malaysia

It has been decided by SPAD, the HSR Malaysia route will be along the coastal area. Malaysia comprises of a wide range of rock types from the sands and silts of the coastal plains to the granite of the Main Range. As shown in Figures 6 and 7, geologists group the rocks according to their type, age and environmental deposition. The most widely used unit for geology reference is based on their formation and giving each type their own geographical names. In Peninsular Malaysia, the geology ranges from Cambrian to the Quartenary, that is from 570 million years to about 10,000 years ago, are represented and are shown in Figure 6. As shown in Figure 7, the proposed HSR route starting from Kuala Lumpur will pass through a carboniferous area, which prominently consists of limestone. The route then will cross granite in the Seremban area. Towards to the south, the alignment will pass through the limestone and sandstone area. In the south bound, the HSR route from Melaka to Nusajaya lies on the coastal area matching with the geology profile of marine and continental deposits. Mostly, the soil conditions are basically in the form of clay, silt and peat [14-19].

Figure 5: Malaysia East Coast Line railway bridge, which cross Nenggiri River in Kemubu, Kelantan had totally lost due to massive flood in December 2014.

According to the observations of the IPCC Working Group 1 Summary for Policymakers (SPM) of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report [9], the evidence for rapid climate change is compelling:

- Global temperature rise
- Sea level rise
- Warming oceans
- Shrinking ice sheets
- Declining Arctic sea ice
- Glacial retreat
- Extreme events
- Ocean acidification
- Decreased snow cover

4. Climate Change and its vulnerable assets

Extreme weather events have occurred frequently in Malaysia the past decade. The most devastating natural disasters experienced in Malaysia are floods and landslides

- **Floods**
- The destructive flood in southern peninsular of Malaysia which occurred in two events back to back in December 2006 and January 2007 are known as Typhoon Utor. The massive flood in Kota Tinggi Johor started when the

Northeast monsoon brought heavy rain through a series of storms. The series of floods were unusual as the 2006 average rainfall return period was 50 years, while 2007 had more than 100 years of return period. Local weather changes are among the natural causes that triggered the flash flood [10].

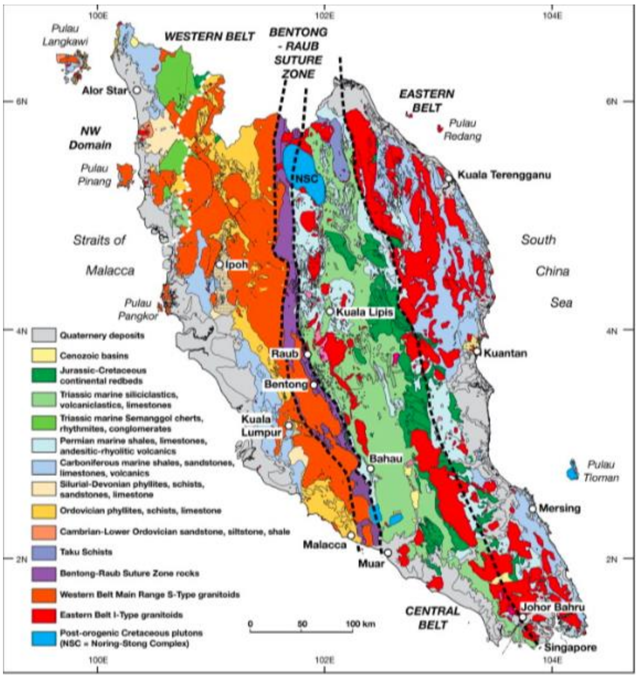
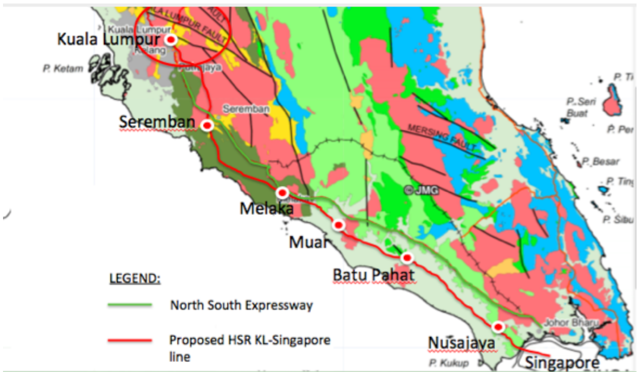


Figure 6: Geology Map of Peninsular Malaysia [14]



QUARTENARY	Marine and continental deposits; clay, silt, sand, peat with minor gravel. Basal of Early Pleistocene age in the Kuantan area.
TERTIARY	Isolated continental basin deposits of Late Tertiary age, shale sandstone, conglomerate and minor coal seams. Volcanics in the Segamat area.
JURASSIC-CRETACEOUS	Continental deposits of thick, cross-bedded sandstone with subordinate conglomerate and shale/mudstone. Volcanics are locally present.
TRIASSIC	Interbedded sandstone, siltstone and shale; widespread volcanics, mainly tuffs of rhyolitic to dacitic composition in Central Peninsular. Limestone prominent in lower part of the succession. Conglomerate and chert are locally prominent.
PERMIAN	Phyllite, slate and shale with subordinate sandstone and schist. Prominent development of limestone throughout the succession. Volcanics, mainly rhyolitic to andesitic in composition are widespread.
CARBONIFEROUS	Phyllite, slate, shale and sandstone; argillaceous rocks are commonly carbonaceous. Locally prominent development of limestone. Volcanics of acid to intermediate composition are locally present.
DEVONIAN	Phyllite, schist and slate; limestone and sandstone are locally prominent. Some interbeds of conglomerate, chert and rare volcanics.
ORDOVICIAN-SILURIAN	Schist, phyllite, slate and limestone. Minor intercalations of sandstone and volcanics.
CAMBRIAN	Sandstone with subordinate silstone, shale and minor conglomerate
PERMIAN-JURASSIC	Intrusive rocks, mainly granite with minor granodiorite.

Figure 7: Geological Map at HSR Malaysia route [14]

- **Landslide**
  - Asia suffers more landslides compared to other world regions due to its climate. According to United Nations University [11], among natural disasters, landslides are the seventh ranked killer, after windstorms, floods, droughts, earthquakes, volcanos and extreme temperatures, in which an average of 940 people annually were killed by landslides in the decade 1993 to 2002, most of those victims being from Asia. There are many factors which can trigger landslides including changes of slope geometry, changes of water level, rainfall intensity, and changes in loading. However, the major cause of landslides in Malaysia is high precipitation [12-13].

Figure 8: The Bukit Lanjan rockfall along the New Klang Valley Expressway, in November 2003, resulted in a six month closure of that particular stretch

Figure 9: The main railway line to Cornwall and Devon was demolished at Dawlish by storms which hit the UK in February 2014 [15]

  - As Figure 8 shows the traffic stuck due to the rock fall but can still swerve and go around the debris but it is different with trains. The trains do not have this option, even if a small landslide occurs on the railway line. This brings greater risk to the trains and passengers. It is important for the infrastructure manager to design the slope and track embankment with the consideration of extreme rainfall due to climate change.

- A study from the UK demonstrates the disruption caused by the impact of weather on railway lines. The wettest winter on record in England and Wales (2013-2014) caused widespread and severe consequences including flooding and disruption to road transport in the Somerset Levels. It also caused the destruction of the South Devon Railway sea wall at Dawlish (refer to Figure 9), severing rail access to and from the counties of Cornwall and Devon and the rest of the country [13].

- Sea Level Rise
  - A rise in the sea level will automatically affect the reading of 100 years flood level in which Malaysian design standard normally adopt when designing the platform level bridge. There are many consequences to the railway infrastructure due to hot and dry weather and the obvious example is the risk of buckling. According to Network Rail, the definition of buckling is the extent of track deformation constituting a reportable buckle is that which would render the line unfit for the passage of trains at line speed and/or necessitates emergency remedial work to a running line under cover of either a temporary restriction of speed or closure of the line. Buckling is very treacherous as it could cause derailment to the train and end up disruption of railway operation service. Figure 10 shows a Singapore bound train derailed on 26th of January 2013 due to rail buckling[5, 14-17]. The wagons landed on their sides and trapped the worker and injuring five passengers. The train service to the southern part of Malaysia was disrupted for several days due to the difficulties of rescuers to reach the remote area where the incident happened.

Figure 10: KTMB train derailed due to rail buckling and had landed on its side, trapping the driver and injuring about five passengers just before the Kempas, Johor station southern part of Malaysia

5. Operational Vulnerability and Adaptation

Malaysia has conducted several studies on the climate change scenarios through Malaysian Meteorological Department and Ministry of Science, Technology and Innovation and several universities. However, there were only a few studies on the threat of climate change to the infrastructure particularly in the railway industry. Research conducted by universities in Malaysia was centred on the climate change impact on agriculture. The Climate Change Act 2008 is an Act of the Parliament of the United Kingdom implemented a process by which statutory authorities, such as Network Rail, are required to comply with formal reporting requirements in respect of climate change adaptation.

Table 1: Proposed planning process for climate change adaption for HSR Malaysia

No.	Planning Component	Purpose
1	Critical weather events	Knowledge and understanding of impact on HSR Malaysia
2	Critical components of HSR Malaysia	Knowledge and understanding of vulnerability to critical weather events
3	Prediction of climate change impact	Methodology for predicting the impact of specific critical weather events on components of the HSR Malaysia
4	Development of adaptation options	Permits evaluation of different adaptation policies
5	Design standards	Identification of changes to design standards to mitigate the impact of climate change
6	Management policy	Identification of changes to management policy to mitigate the impacts of climate change

According to Lane and Dora [14], in order to undertake the required reporting process, it is firstly necessary to identify the key activities that are required, to develop a reliable method for the prediction of climate change impact as shown in Table 1. In this case, Malaysia HSR could adopt this planning process and perhaps this policy can be the guidance to the other rail operators such as KTM and Rapid KL [18-19].

6. Conclusions

The Paris Agreement in late 2015 strengthens the collaborative work on global warming reduction. As climate change is real and unequivocal, Malaysia is required to assess the risks of climate change especially to the railway operation. There was a lack of studies on the effect of climate change to the Malaysian railway operation and as well to the railway infrastructures. Now that Malaysia is planning to build new HSR, mitigation and adaption measures to the risk of climate change are a must to ensure that we can achieve and deliver: a safe railway; a high reliable railway; increased capacity; value for money; and a predict and prevent ethos.

The risk and venerability from climate impacts to the operation of HSR Malaysia has thus been highlighted in this paper. The insight into the climate change potentials has led to the development of adaptation measures for the newly proposed HSR between Malaysia and Singapore. Such measures can be integrated into the design and preparation stages so that the infrastructure resilience is built in, improving public safety and reliability.

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